Reduction of Martian Sample Return Mission Launch Mass with Solar Sail Propulsion

Tiffany E. Russell
NASA, George C. Marshall Space Flight Center ED04, AL 35812
Phone: 256-961-1304
Tiffany.E.Russell@nasa.gov

Andy F. Heaton
0NASA, George C. Marshall Space Flight Center EV42, AL 35812
Phone: 256-544-3839
Andrew.F.Heaton@nasa.gov

Roy Young
NASA, George C. Marshall Space Flight Center ES31, AL 35812
Phone: 256.544.0283
Roy.Young@nasa.gov

Mike Baysinger
NASA, George C. Marshall Space Flight Center ED04, AL 35812
Phone: 256.961.0295
Mike.baysinger@nasa.gov

Andrew R. Schnell
NASA, George C. Marshall Space Flight Center ER24, AL 35812
Phone: 256-544-8913
Andrew.Schnell@nasa.gov

Condensed Abstract

Solar sails have the potential to provide mass and cost savings for spacecraft traveling within the inner solar system. Companies like L'Garde have demonstrated sail manufacturability and various in-space deployment methods. The purpose of this study was to evaluate a current Mars sample return architecture and to determine how cost and mass would be reduced by incorporating a solar sail propulsion system. The team validated the design proposed by L'Garde, and scaled the design based on a trajectory analysis. Using the solar sail design reduced the required mass, eliminating one of the three launches required in the original architecture.

Extended Abstract

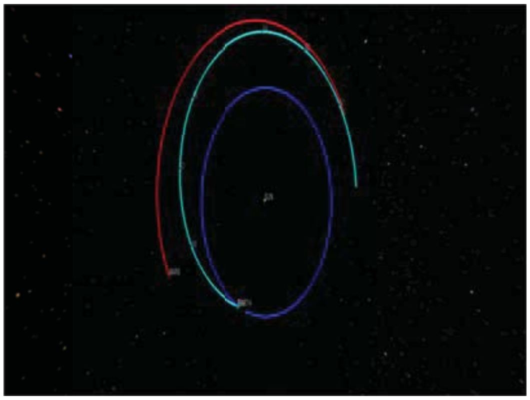
Utilizing solar sails instead of traditional chemical propulsion can provide mass and cost savings for interplanetary travel within the inner solar system [1]. L'Garde and other private ventures have proven both the manufacturability of solar sail materials and various in-space deployment methods. This study involved the incorporation of an existing design of a solar sail for a Solar Sail Technology Demonstration Mission [2] by L'Garde called Sunjammer [3]. The sail design would be applied to the propulsion system of an existing Mars Exploration Sample Return Mission Architecture [4,5,6] developed by the Jet Propulsion Laboratory. The solar sail is currently in manufacturing development phases in support of NASA's Office of the Chief Technologist Advanced In-Space Propulsion Systems [7]. The purpose of this study was to estimate the reduction of mission cost and mass for an existing architecture through the inclusion of the solar sail.

The point of departure for this study was the Mars Exploration Sample Return Mission Architecture [4,5,6] which requires separate launches of an exploration rover, an orbiter with an Earth return stage, and a Martian ascent vehicle with a sample return canister. The current launch manifest spans six years with operations lasting an additional 4 years and costs totaling billions of dollars. Reducing the number of launches would significantly drive down mission cost and timeline.

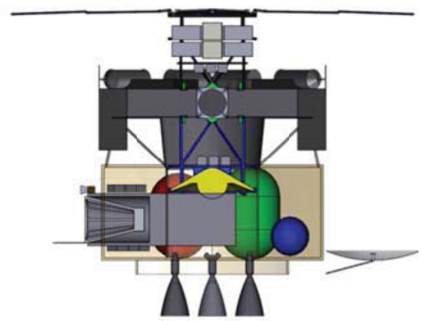
The team developed a trajectory [Figure 1(a)] that took advantage of the unique properties of solar sail propulsion. This allowed them to scale the size of the solar sail required for the mission from the current Sunjammer design [8]. The power system was tweaked to reduce mass by replacing the current power management system with a lower mass design from the original orbiter design. The incorporation of proven flight system avionics from existing spacecraft was identified as a way to reduce mass and risk. A preliminary thermal analysis showed that the temperatures required for the spacecraft and sail could be maintained using flight-proven components. A structural analysis showed that the solar sail and its deployment system could be incorporated into a modified version of the original orbiter design [Figure 1(b)].

Two additional trades were performed to determine the impact of using a solar sail system. The first involved using traditional chemical propulsion to get from Earth to Mars, then a solar sail was deployed to return the Mars sample to Earth. A second trade consisted of solar sail propulsion on both trips. The team determined that the architecture could not support the orbiter and exploration rover on the same launch vehicle if the solar sail were only utilized during Earth return. However, if the orbiter used a solar sail as its main propulsion method for transit to and from Mars, the orbiter would be able to launch with the exploration rover eliminating the need for one of the three launches.

The team was able to repackage the orbiter, the exploration rover, and the sample return vehicle to allow stowage and deployment of the solar sail. The team concluded that the addition of the solar sail [Figure 1(c)] for the trip to Mars and back to Earth eliminated the need for one of three planned launches. The team estimated that even with the reduced mass, all mission requirements would be met. Future work would involve re-evaluating launch vehicle options and further design modifications to the spacecraft to further reduce mass.



(a)



(b)

(c)

Figure 1. (a) Mars-Earth trajectory for Martian sample return mission with solar sail. (b) The Mars Sample Return probe. (c) The sample return probe with a deployed solar sail.

References

1. Forward, R.L. "Solar Sail Mission Requirements: Final Report." Forward Unlimited. JPL Purchase Order No. 1208842. 2000.
2. Boen, Brooke, ed. "NASA - NASA Technology Demonstrators (TDM) Home Page." NASA, 28 Jan 2013. Web. 29 Jan 2013. <http://www.nasa.gov/mission_pages/tdm/main/index.html>
3. Barnes, N. "Sunjammer Solar Sail Demonstration." L'Garde, Inc. NM11AA54C Fifth Gossamer Workshop, Tustin CA. 2012.
4. Christensen, P. "MSR Lander Mission." White Paper. Planetary Science Decadal Survey. Arizona State University. 2010.
5. Christensen, P. "MSR Orbiter Mission (Including Mars Returned Sample Handling)." White Paper. Planetary Science Decadal Survey. Arizona State University. 2010.
6. Arvidson, R. "Mars 2018 MAX-C Caching Rover." White Paper. Planetary Science Decadal Survey. Washington University School of Medicine. 2010.
7. Meyer, M., Johnson, L., *et al*. "Roadmap for In-Space Propulsion Technology." NASA. NASA/TM-2012-217641. 2012.
8. Lichodziejewski, D. "In-space propulsion solar sail executive summary." L'Garde, Inc. LTR-05-LL-41, NASA Contract No. NAS8-03046. 2005.